Idaho National Engineering and Environmental Laboratory

DEVELOPMENT OF A MINE COMPATIBLE LIBS FOR ORE GRADING

One of the key goals of the National Mining Association's recently established vision statement is a strategy to develop technologies for superior exploration and resource characterization. Resource characterization can be improved by performing direct analysis of the ore during the extraction process in order to avoid low-grade dilution. Presently no instrument is available to provide reliable, in-situ analysis in real-time for grading the ore during the extraction process. This problem has been identified as an important concern by many open-pit mining organizations. Significant savings in processing costs and energy use can be achieved by developing an instrument for in-situ element analysis enabling the operators to 'real time' selectively extract the highest quality ore. Laser Induced Breakdown Spectroscopy (LIBS) is an important new analysis technology that permits fast, direct, inorganic analysis without sample preparation. The objective of this research program is to develop, configure, integrate and demonstrate a robust LIBS instrument, including a hand held fiber-optic probe, software interface, and the associated methods to accomplish real-time ore grading.

Statement of the Problem and Technology Concept

This project addresses the goal of developing a technology for improving the efficiency of mineral ore extraction through 'real time' measurement of ore quality. This enables reduction of out-of-seam dilution, significantly reducing mineral processing costs and energy costs. Presently, most surface mining operations must rely on laboratory-based analysis to monitor the extraction process. This requires samples to be collected, transported to the instrument, analyzed, recorded, and the data transmitted back to the pit location. This process is slow, subject to numerous errors, and does not support real time management of the extraction process. The best existing option for 'in-situ' inorganic analysis is based on X-ray fluorescence. However, these instruments cannot measure light elements effectively, contain radioactive sources that must be regulated, and lack the detection limits necessary for many operations. Consequently, operations are forced to rely on centralized analysis laboratories. Laser induced breakdown spectroscopy (LIBS), also sometimes referred to as laser optical emission spectroscopy, is an ideal analytical method for real-time quantitative analysis of inorganic elements in solids and liquids and requires no sample preparation. In laser spectroscopy, a laser pulse is focused to a spot just above the sample surface. The intense radiation initiates a series of processes including the formation of a hot plasma cavity above the sample that ablates a small amount of material from the sample surface into the hot plasma cavity. Ablated atoms that enter the plasma region are dissociated and ionized. Time-resolved optical emission spectra are collected from the plasma fireball and analyzed to determine the wavelength and intensities of the line radiation from constituent elements of the sample material. The major lines in this data are then compared with a stored database to determine the identity and the concentration of the constituent elements. Using this technique, sensitivities of parts-per-million (ppm) have been achieved for a variety of elements in different sample matrixes.

Objective: In the proposed effort, scientists in the Optical and Plasma Physics Department at the Idaho National Engineering and Environmental Laboratory will team with industry and academic partners for the purpose of developing and demonstrating a LIBS instrument specifically configured for real-time, open-pit mine face ore grading. The INEEL group has extensive experience in the development and application of optical

instrumentation, including a recent project funded by DOE EM-50 to monitor plutonium contaminated dust using the LIBS technique. The goal of this effort was to develop an in-situ monitoring device for the rapid screening of particulate generated during remediation activities for the purpose of reducing personnel hazards and controlling the spread of contamination. Other areas of research include plasma and flow field diagnostics, applied spectroscopy, fiber optic sensor development, and laser-assisted processing. Specialized sensor and diagnostic packages, including high speed grating spectroscopy, pulsed-laser spectroscopy, radiometry and specialized imaging systems have been fielded. Efforts include the design and fabrication of optical systems, as well as the development of analog signal processing and digital data acquisition. One industry partner has recently performed a multi-year program to develop a robust LIBS instrument for on-line mineral process control in extremely harsh environments. A picture of the proposed instrument is shown in Figure 1.

While this project is directed at open-pit phosphate mining, it should be noted that since the instrument is able to detect any inorganic species, it can be used for a variety of industrial monitoring and process control applications. Examples range from the process control of steel production to the monitoring of off-gas emissions from thermal waste treatment processes.

Figure 1. Proposed Ore Characterization Instrument

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